Human Influence Past and Present – Relationship of Nutrient and Hydrologic Conditions to Urban Wetland Macrophyte Distribution[1]

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ABSTRACT. Urban wetlands can provide valuable ecological services through filtration and moderation of non-point source pollutants. They provide habitat for wildlife, green space, and recreational opportunities for nearby human populations. We investigated an isolated section of an urban wetland in the Cleveland metropolitan area to determine the overall quality of the vegetation and to evaluate the site for possible rehabilitation. We also researched the distribution of plant species in relation to existing hydrologic, soil, and nutrient conditions in order to identify possible impacts of historic or present human activities in the surrounding watershed. Vegetation composition and physical/chemical parameters were measured in 1.0 × 1.0 m² plots along three transects. Canonical correspondence analysis (CCA) was used to directly correlate species distributions to nutrient concentrations, soil carbon content, and water depth. Our sample area was dominated by *Typha angustifolia*, *Leersia oryzoides*, and *Sparganium eurycarpum*. A few high quality species were present, but the overall macrophyte community was indicative of human disturbance. Historic information revealed a long history of disturbance at the site and continuing anthropogenic impact. Patchiness in nutrient and water depth gradients results from historic and current human impacts in the study area. Our results indicate any rehabilitation efforts of the site need to take into account past and current anthropogenic stressors. We recommend aggressive removal of invasive species and re-introduction of nutrient-tolerant native taxa to achieve successful rehabilitation at the site.

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INTRODUCTION

The value of wetlands in mediating and processing watershed inputs is well known. They provide valuable ecological services including groundwater recharge and water quality improvement, as well as providing fish and wildlife habitat (for example, Mitsch and Gosselink 2000). More than 90% of Ohio's wetlands have been lost as a result of human related activities (Dahl 1990). It is, therefore, all the more important that we work to rehabilitate and restore those wetlands that remain. Present day urban wetlands are particularly vulnerable to loss. They often function differently as a result of surrounding land-use practices that alter hydrology and increase nutrient inputs. Many of these wetlands are small, isolated 'islands' in the urban landscape. Often they are perceived of as 'disposable' or of little significance. However, they contribute to the ecological integrity and biodiversity of the regional landscape by providing stopover spaces or refugia for migrating and regional wildlife. Additionally, in contrast to their rural counterparts, urban wetlands provide human-related services such as green space and recreational opportunities that otherwise are limited in urban environments (Ehrenfeld 2000).

Lake Abram, Cuyahoga County, OH (41.3789° N, 81.8388° W) lies in the Rocky River catchment and is surrounded by extensive wetlands, the majority of which lie south and west of the lake (Fig. 1). The site is a recent acquisition of the Cleveland Metro Park system. Once part of the extensive Podunk Swamp, the wetland has shrunk from an original size of several hundred acres to a mere 80 acres at present due to extensive human modification and increased urbanization. Despite this loss, it remains the largest natural wetland in Cuyahoga County. Lake Abram and its surrounding wetland lie in a glacial kettle. It is categorized as a riparian, kettle lake, depressional wetland (Mack and others 2000). Today, the wetland is surrounded on all sides by varying amounts of residential, commercial, and industrial development.

Land-use impacts on wetlands may manifest themselves through changes in plant communities, altered

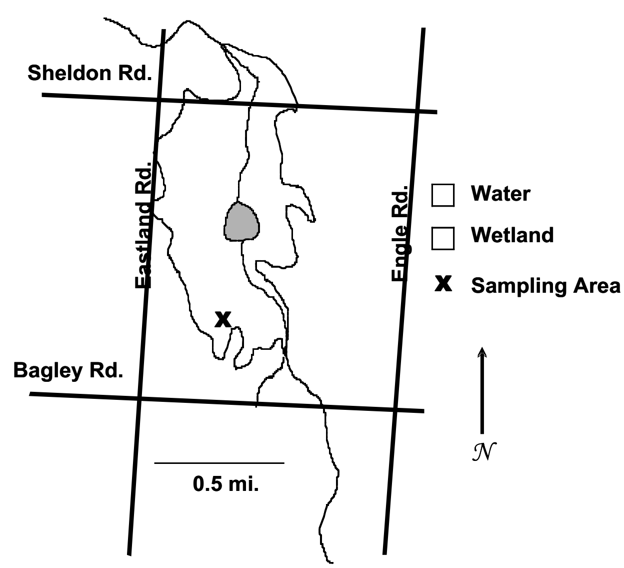

FIGURE 1. Map of the Lake Abram wetland site indicating location of sampling area.

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hydrologic regimes, or increased nutrient and chemical pollutant inflows (Galatowitsch and others 2000). The effects of these impacts may be minor or occur in small increments over time and therefore remain unnoticed while still at low levels. Different types of disturbance, for example hydrologic alterations that result from stormwater drainage or increased impervious surfaces, will influence the response of wetland vegetation communities in various ways. Woo and Zedler (2002) observed a shift from diverse wetland plant communities to *Typha* dominated ones with changes in hydrology and nutrient inflows.

Land-use disturbances surrounding wetlands can also increase their vulnerability to invasion by nuisance species through changes in hydrology, soil, or canopy cover, as well as the impact of nutrient and chemical pollutants (Woo and Zedler 2002; Green and Galatowitsch 2002). This results in a wetland dominated by a few species and a diminished biotic diversity that in turn modifies ecosystem function (Green and Galatowitsch 2002).

According to the Ohio Environmental Protection Agency (OEPA), Vegetation Index of Biotic Integrity (VIBI, Mack and others 2000), the Lake Abram wetland is a Class I/II emergent marsh. Wetlands classified at this level are impaired sites with minimum to moderate function and/or integrity. Despite this vegetation classification, the wetland provides valuable habitat for numerous migrating birds, waterfowl, amphibians, and mammals including a large urban deer population. It provides an outdoor laboratory for students at nearby Berea High School, Baldwin Wallace College, and Cleveland State University, and has excellent potential for public environmental education on wetland ecology and conservation. The Cleveland Metro Parks is interested in identifying potential areas for wetland rehabilitation; however, little baseline information exists on physical-chemical or vegetation characteristics for the site.

A survey conducted by students at Baldwin Wallace College in 1983 provides some indication of past vegetation communities. Presently, stands of *Phragmites australis* exist along the western edge of the marsh near the open lake and *Typha angustifolia* appears to be a dominant throughout most of the wetland. A current project investigating the effects of stormwater inflow on vegetation distribution in the southwestern section (J. Wolin, unpublished data) identified the presence of higher quality macrophytes (for example, *Asclepias incarnata*, *Typha latifolia*). We further investigated this region to determine if it may function as a possible refugia site for higher quality wetland plants. The site is somewhat isolated from the main section of the marsh and we hypothesized that its isolation may inhibit invasion of less desirable species present in other areas. Our objectives in this study were as follows: to describe the plant species present in this isolated section and categorize them according to their Coefficient of Conservatism (Andreas and Lichvar 1995) in order to determine overall quality of the community; and to investigate the distribution of plant species in relation to existing hydrologic, soil, and nutrient conditions in order to determine possible impacts of historic or present human activities in the surrounding catchment.

MATERIALS AND METHODS

Our initial site survey was conducted in early October 2003 to determine the community structure of the site and compile a preliminary species list (Tiner 1999). The sampling and analysis of the vegetation plots were conducted over several field days between 3 – 27 October 2003 prior to first frost. Line transects were used to determine the vegetation composition. A main transect (A, 60 m) bisected the study area from the southern edge to the northern edge of the study plot. Two side transects were run perpendicular to the main transect at 1/3rd (transect B, 40 m) and 2/3^{rds} intervals (transect C, 30 m). Transects were marked with line and sampling points were marked every 10 m with flagging tape and a surveyors flag. The vegetation and physical-chemical data were obtained from 1 × 1 m^2 plots at each sampling point. The plots were randomly placed on alternating sides of the transect line, one meter away from the respective lines. This resulted in six plots along transect A (A10-A60), four plots on transect B (B10-B40), and three plots on transect C (C10-C30) for a total of 13 sample plots.

The plants in each plot were measured using percent aerial coverage (Tiner 1999). This percentage is determined separately for species in each vegetation layer. Our site contained three vegetation layers and percent aerial coverage for all species is greater than 100%. Any nearby plants observed outside of the plots were added to the total species list for the site. Extreme caution was taken to minimize impact to the area and only those plant specimens necessary for identification were collected. Plants were assigned a wetland designation (obligate, facultative wetland, or facultative), annual or perennial status, and native or non-native species according to the United States Department of Agriculture, Natural Resources Conservation Services (USDA, NRCS) on-line plant database (2003). Designations of plant Coefficient of Conservation (C of C) and Floristic Quality Index (FQI) were determined using Andreas and Lichvar (1995).

Water chemistry data were collected on 31 October 2003. Measurements of pH, temperature, dissolved oxygen, conductivity, water level, and soil samples were collected at each plot. A soil probe was used to extract soil samples. These samples were described in the field using a Munsell Soil Color Chart. Soil samples for loss-on-ignition were taken from within the root zone and placed in labeled containers for transport to the laboratory. A 12-inch diameter hole was dug to a minimum depth of 12 inches at the center of each plot and water allowed to settle approximately 20 minutes before measuring physical parameters and obtaining water samples. In the field, dissolved oxygen (%) and conductivity were measured using an YSI Model 85® handheld meter and pH was measured with an Orion model 250A® portable meter. Dissolved oxygen values are reported as % saturation for comparative purposes since oxygen concentration in mgl^{-1} is temperature dependent and temperature varied between sites. Water samples were collected in dry, acid-rinsed 500 ml Nalgene® bottles. Bottles were rinsed twice with sample water at each study plot taking care to dispose of rinse water away from the site. Standing water depth was measured at the center of each plot with a meter stick using the soil surface as 0.0 cm. Water depth measurements for those plots containing no standing surface water were taken from the water sampling hole within the plot. Water depth was recorded as distance from the soil surface to the water level within the hole. Standing water above the soil surface is reported as a positive value while water below the soil surface is negative.

Water samples were kept cold and analyzed within 24 hours of sampling for nitrate (NO_3), orthophosphate (PO_4), and ammonia (NH_4). Analyses followed standard USEPA approved chemical methods (Standard Methods for the Examination of Water and Wastewater 1998) using pre-measured HACH® chemical reagents. Nutrient concentrations were measured with a Thermospectronic Aquamate® spectrophotometer.

The organic carbon composition of the soil samples was estimated using loss-on-ignition techniques (Dean 1974). Weighed subsamples were taken from each soil sample and oven dried at 90° C for 24 hrs to remove excess water. These subsamples were placed in a 550° C muffle furnace for 3 hours. Organic matter was determined by calculating loss of mass at 550° C from the original dry weight. The remaining unburned material represented the soil mineral fraction.

The physical-chemical data were summarized by determining means and variance for each transect and the differences between transects were tested for significance using a two-tailed *t*-test. Canonical correspondence analysis (CCA) was run on the macrophyte and environmental data using the program CANOCO 4.5 for Windows (ter Braak and Smilauer 2002). CCA is an unconstrained ordination technique that allows us to identify major changes in assemblage composition. It directly compares species distribution with environmental variables. The analysis not only reveals patterns of species distribution by site, but also statistically determines the strength of environmental variables in explaining variance within the species data (ter Braak 1995). The data were analyzed with canonical correspondence analysis (CCA) using taxa which comprised 10% cover or greater in at least 1 plot and were present in at least 2 plots in any given transect. An initial CCA was run using all environmental data to determine those data that were important in determining species distributions. Subsequent analyses were run using a subset of these data. An additional CCA was run by removing plot B20 (a unique plot in the data set) in order to further define macrophyte/environmental associations for the remaining plot sites.

Human impacts at the site and surrounding area were determined from written historic records obtained from the Western Reserve Historical Society and analysis of Ohio Department of Transportation (ODOT) aerial photo series taken between 1958 and 1999.

RESULTS

A total of 28 species were found at the site (Table 1). Only one plant species (*Galium trifidum*) in the sampling area had a C of C above 6, which would be indicative of unaltered communities. Eight species had C of Cs from 4-6 and represent transitional (altered and unaltered) communities. Nineteen species denote degraded communities with C of Cs ranging from 0-3. The FQI score for the site was 15, which signifies an altered vegetation community. The community was dominated by perennials (24); only 5 species were identified as annuals. At least 3 non-native species were present.

Data from visual surveys and sample plots showed the wetland site was dominated by *Leersia oryzoides* (12 plots) and *Typha angustifolia* (10 plots) (Fig. 2). *Sparganium* was dominant in one sample plot (A20). The *T. angustifolia* population in sample plot B40 and the surrounding area was noticeably taller and denser than populations in any other section of the study area. *Leersia oryzoides* was densely matted throughout most of the study site and in many cases appeared to cover entire plots. Sample plot B20 was the most diverse site with a total of six species. It was also the most open plot site, possibly due to deer activity. Dominant plants included *Mimulus ringens* and *Pilea fontana*. Total number of species per plot ranged between four and six.

The pH measurements from sample plots ranged from a pH 6.78 - 8.03 and classify the site as an alkaline wetland. Due to a meter malfunction part-way through field data collection, we did not obtain reliable data from all sites and pH measurements were not included in our CCA.

Conductivity varied from 1.6 mV to 63.8 mV throughout the study site, but was noticeably higher at plots A50, A60, B20, C20, and C30 (Table 2). Transect B had the highest mean conductivity measurements, although due to the high variability between sample plots, they were not statistically different from other transects.

The percent saturation of dissolved oxygen (Table 2) was relatively low and showed a wide range of variation from 0.7% to 40.2%. Mean percentages although not significant were highest in transect C. The highest saturation was found at plot C10 (40.2%) and the lowest at plot C20 (0.7%). Plot C10 was closest to the open region of the marsh that surrounds Lake Abram and may be subject to higher surface and sub-surface water flow. Along transect A, percent saturations increased from plot A10 to A30, before declining from A40 to A60. Oxygen saturations in this transect ranged from 15.7% to 26.5% with highest readings at A30. An increasing trend was present along transect B from plots B20 to B40 (8.4% to 28%, respectively). Oxygen data are missing for plot B10.

The water depths (Table 2) varied from -2.5 cm below to +5.0 cm above the soil surface. A surface water gradient was present along transect A. Depth was highest at plots A10 and A20 (+3.5 cm), declining to +1.5 cm at plot A60. A decline in water level was also evident along transect B between plots B10 to B30 with lowest overall measured levels at sites B20 (-1.5 cm) and B30 (-2.5 cm). Sample plot B40, only 10 m from

Table 1

Total species list for wetland vegetation at sampling site October 2003.

Species	Designation*	Native	Duration	C of C**
Acer rubrum L.	FAC	Yes	Perennial	2
Acer saccharinum L.	FACW	Yes	Perennial	3
Asclepias incarnata L.	OBL	Yes	Perennial	5
Bidens frondosa L.	FACW	Yes	Annual	2
Eupatorium perfoliatum L.	FACW+	Yes	Perennial	3
Impatiens (*capensis?*) L.	FACW	Yes	Annual	2
Cornus L.			Perennial	
Echinocystis lobata (Michx.) Torr & Gray	FAC	Yes	Annual	3
Scirpus cyperinus (L.) Kunth	FACW+	Yes	Perennial	1
Onoclea sensibilis L.	FACW	Yes	Perennial	3
Scutellaria lateriflora L.	FACW+	yes	Perennial	3
Lythrum salicaria L.	FACW+	Introduced	Perennial	0
Epilobium coloratum Biehler	OBL	Yes	Perennial	2
Ludwigia palustris (L.) Elliot	OBL	Yes	Perennial	4
Leersia oryzoides (L.) Sw.	OBL	Yes	Perennial	1
Phragmites australis (Cav.) Trin. ex Steud.	FACW	Introduced	Perennial	0
Polygonum arifolium L.	OBL	Yes	Annual	4
Polygonum sagittatum L.	OBL	Yes	Annual/Perennial	3
Galium trifidum L.	FACW+	Yes	Perennial	7
Mimulus ringens L.	OBL	Yes	Perennial	5
Solanum dulcamara L.	FAC-	Introduced	Perennial	0
Sparganium cf. eurycarpum Engelm. ex Gray	OBL	Yes	Perennial	4
Typha angustifolia L.	OBL	Introduced	Perennial	0
Typha latifolia L.	OBL	Yes	Perennial	2
Typha (*x glauca*) L.	OBL	Yes	Perennial	0
Boehmeria cylindrica (L.) Sw.	FACW+	Yes	Perennial	4
Pilea fontana (Lunell) Rydb.	FACW+	Yes	Annual	4
Urtica dioica L.	FACU	Native or Introduced	Perennial	1
Verbena hastata L.	FACW+	Yes	Biennial/Perennial	4
Number of native species recorded	23			
Floristic Quality Assessment Index (FQI)	15.01			

*FAC = Facultative; FACU = Facultative upland; FACW = Facultative wetland; OBL = Obligate
**C of C = Coefficient of Conservatism

B30, was the deepest standing water site at +4.5 cm. Mean surface water levels were highest along transect C which varied from +3.0 cm at C30 to +5.0 cm at plot C20.

Soluble reactive phosphorus (SRP) concentrations varied widely throughout the study area and averaged (0.58 mgl^{-1}). Highest concentrations (1.01 mgl^{-1}) were found at plots A50 and B10 (Table 2). A decreasing trend in concentrations is seen along transect A from plots A10 to A40 before increasing at plots A50 and A60. Lowest SRP concentrations were measured at plots A40 (0.04 mgl^{-1}), B20 (0.02 mgl^{-1}) and C10 (0.05 mgl^{-1}). Nitrate concentrations were notably higher in plots A10 (1.8 mgl^{-1}), B10 (4.7 mgl^{-1}) and B30 (3.8 mgl^{-1}). Nitrate was non-detectable at sites A20-A40, B40, and C10. Mean nitrate concentrations were lowest along transect C with plot C20 exhibiting the highest value along the transect. Ammonia concentrations also varied throughout the study plots with an average of 1.14 mgl^{-1}. Highest concentrations were at plots A10 (1.97 mgl^{-1}), B10 (2.08 mgl^{-1}) and B40 (2.58 mgl^{-1}) and lowest at

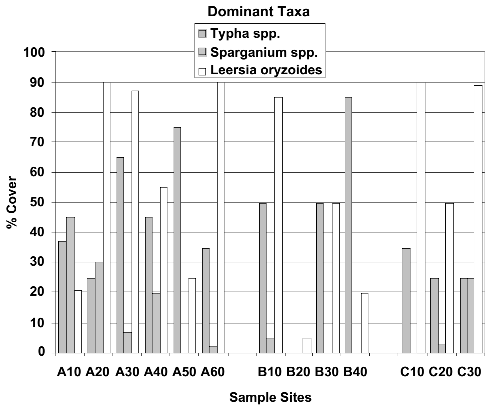

FIGURE 2. Percent cover of dominant taxa by transects and sample plot.

plots B30 (0.31 mgl^{-1}) and C10 (0.29 mgl^{-1}) (Table 2). With the exception of plot A10, concentrations were lower along transect A, but showed an increasing trend from plots A20 to A60. Concentrations along transect B indicate a decreasing trend in ammonia, with the exception of plot B40.

The soils are composed of Carlisle silty-clay-loam, very poorly drained and subject to frequent flooding and ponding (Musgrave and Holloran 1980). All samples were identified as 10-YR with a value of 2 or 3 and a chroma of 1 or 2, depending on the sample plot. Loss-on-ignition data indicated organic soils dominated the site and % organic carbon ranged from about 20 to 40% at all but one plot (Table 2). Sample plot B40 contained the highest percentage organic carbon at 50%. Transect A plots averaged 35% organic carbon, transect B was highest with an average of 42%, excluding B40, and

TABLE 2

Physical-chemical data for all plots 31 October 2003.

PLOT	Conductivity (mV)	DO (%)	Water Depth (cm)	PO_4 (mgl^{-1})	NO_3 (mgl^{-1})	NH_4 (mgl^{-1})	% Water	% Carbon
A10	34.4	15.7	3.5	0.76	1.79	1.97	63.54%	34.21%
A20	14.8	23.7	3.5	0.60	0.00	0.47	62.89%	29.43%
A30	31.6	26.5	3.0	0.47	0.00	0.67	61.64%	30.15%
A40	1.6	26.0	2.5	0.05	0.00	0.64	56.63%	39.85%
A50	49.0	15.8	1.5	1.01	0.61	1.28	65.39%	37.42%
A60	47.8	4.9	1.5	0.79	0.94	1.34	59.35%	38.22%
Mean	29.87	18.77	2.58	0.61	0.56	1.06	61.57%	34.88%
SD	18.64	8.33	0.92	0.33	0.72	0.57	0.03	0.04
B10	37.7	0.0	0.5	1.01	4.75	2.08	55.50%	42.95%
B20	63.8	8.4	-1.0	0.02	0.52	0.72	57.00%	38.90%
B30	37.6	22.0	-2.5	0.84	3.84	0.31	60.04%	42.95%
B40	34.4	28.0	4.5	0.50	0.00	2.58	67.51%	50.19%
Mean	43.38	14.60	0.38	0.59	2.28	1.42	60.01%	43.75%
SD	13.70	12.73	3.01	0.44	2.37	1.08	0.05	0.05
C10	3.5	40.2	4.0	0.15	0.00	0.29	61.42%	22.68%
C20	60.1	0.7	5.0	0.70	0.62	1.39	61.53%	36.27%
C30	55.7	26.3	3.0	0.60	0.37	1.10	55.93%	25.31%
Mean	39.77	22.40	4.00	0.49	0.33	0.92	59.63%	28.09%
SD	31.48	20.04	1.00	0.29	0.31	0.57	0.03	0.07

transect C was lowest at 28%.

Results of CCA using all sites (Fig. 3) indicated that the majority of the species-environmental relationship was explained by the first and second axes. Fifty-five percent of the variance in the data was explained on the first axis and an additional 25.6% was explained on the second, totaling 80.6%. Eigen values for the first, second and third axes were 0.219, 0.102, and 0.069, respectively. Results of CCA after deletion of sample B20 reduced Eigen values on the first, second, and third axes to 0.108, 0.073, and 0.025, respectively (Fig. 4). However, there was little change in the importance of the first axis and deletion improved the strength of the second axis in explaining the data. Fifty percent of the variance in the species-environmental data was explained by the first axis and an additional 33.7% by the second. Total cumulative variance for axes 1 and 2 equaled 83.7%.

Results of CCA with all sample plots indicated the primary environmental variables determining plant distribution were, in order of importance: % carbon content of soil, conductivity (mV), and depth of surface/sub-surface water (Z) (Fig. 3). The orientation of plot B20 indicated this site was distinct from other sites in both macrophyte composition and environmental conditions. Removal of plot B20 from the ordination reduced the influence of conductivity in determining distribution of plants and increased the influence of NH_4 (Fig. 4).

Typha-dominated plots (A50 and B40) were positively correlated with nutrient concentrations, particularly PO_4 and NH_4, and increased soil carbon content. Plots in which *Sparganium* was dominant or sub-dominant (A10, A20, A40, and C30) were positively correlated with surface water depth, whereas plots dominated by *L. oryzoides* (A20, A30, A60, B10, and C10-30) were correlated with lower nutrient concentrations and % carbon content. Sample plots A40 and B30 were co-dominated by *Typha* and *Leersia*.

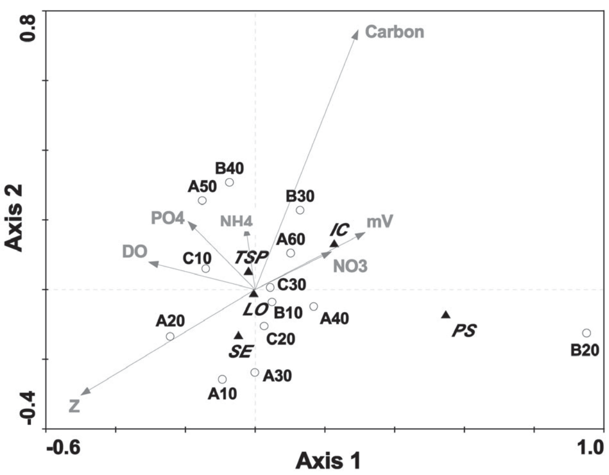

FIGURE 3. Canonical correspondence analysis (CCA) triplot of species (triangles) and environmental variables (arrows) by sample (open circles). Arrows represent Eigen vectors for given environmental variables. Carbon = % soil carbon, DO = % dissolved oxygen, Z = water depth, mV = conductivity, nutrients are as indicated. *TSP* = *Typha angustifolia*, *IC* = *Impatiens capensis*, *PS* = *Polygonum sagittatum*, *LO* = *Leersia oryzoides*, and *SE* = *Sparganium eurycarpum*. Sample plots are as indicated.

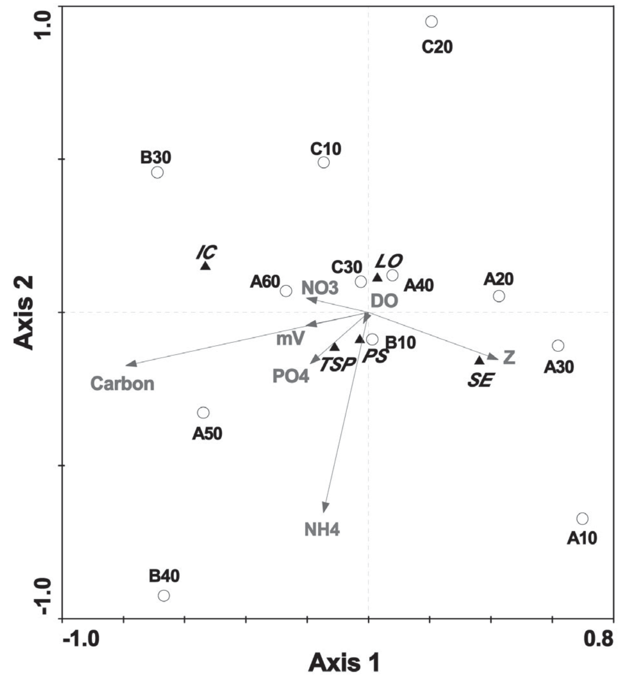

FIGURE 4. Canonical correspondence analysis (CCA) triplot with sample B20 deleted. Environmental variables and plant species are defined as in Figure 3.

DISCUSSION

Historic records (Pease 1795) indicate that Lake Abrams once extended further south and west near the intersection of Bagley and Eastland Roads (Fig. 1). Part of the lake and wetland was drained in 1874 through a northern outlet and the exposed rich organic mud was used for onion and celery farming. Our survey site lies in a depression northeast of this intersection and is almost certainly former lake bottom. As such, it is not expected to contain a remnant macrophyte seed bank. If one existed, farming activities in the 70+ years following drainage would have eliminated it.

Aerial photos obtained from ODOT, clearly indicate that tilled farm fields existed on our site in 1958 and persisted at least until 1963. Subsequent photos taken in 1974 indicate the fields were abandoned and that wetland vegetation had colonized the study site by this time. A man-made channel cutting through the upper third of the study area is clearly evident in a 1986 photograph and in the transect C region. No such channel was obvious during any of our site surveys. The presence of an overgrown pre-existing channel could account for higher surface water measurements, higher percent oxygen, and lower nutrient concentrations found at plots along this transect. Increased surface and sub-surface water movement through a pre-existing channel would result in higher dissolved oxygen, greater microbial decomposition, and lower soil carbon content at these sites.

High nutrient concentrations, particularly NO_3, found at plots A10, B10 and B30 may indicate the presence of septic seepage into ground water from nearby homes.

Marsh vegetation distribution is often determined by varying hydrologic gradients and nutrient levels (Willis and Mitsch 1995) and the CCA of species and environmental data confirms this relationship for the dominant species in our sample area (Figs. 3,4).

Draining wetlands can significantly increase *Typha* cover and contribute to an overall loss of diversity (Mallik and Wein 1986). In particular, *Typha angustifolia* can survive hydrologic fluctuations and is prevalent in storm-water wetlands (Galatowitsch and others 2000). It has been associated with flooded conditions needed for germination (Kellogg and others 2003), increased nutrients, and is a recognized invader of disturbed habitats Wilcox (1995).

Site B40 was one of two sites with standing water above 3.0 cm and contained the densest stand of *T. angustifolia*. The water level is most likely related to the proximity of residential areas. Increased surface run-off occurs due to greater imperviousness and alters wetland hydrology in urban areas (Woo and Zedler 2002). Woo and Zedler also noted that water level alone is not responsible for *Typha* invasions and that nutrients play a major role in wetland community structure. CCA indicates that *T. angustifolia* population distributions correspond most strongly to higher nutrients and soil carbon content. Mean NO_3 and NH_4 concentrations, though not significant, were highest in transect B and these plots had the highest nutrient concentrations of all sites. Plot B40 soils were also highest in organic carbon. Nearby residential areas contribute excess nutrients and salts from road runoff and/or water softening agents facilitating the presence of *T. angustifolia* (Woo and Zedler 2002). Wilcox (1995) reported that *T. angustifolia* dominated disturbed areas contaminated by road salt at the Indiana Dunes National Lakeshore and higher conductivity measurements along transect B indicate elevated salt concentrations are present.

Leersia oryzoides (rice cut-grass) was also dominant in the study plots. It is a native, perennial species with intermediate competitive abilities (Kellogg and others 2003). Results of CCA indicate *Leersia* is correlated with lower nutrient concentrations and organic carbon than *Typha* and *Sparganium* (Figs. 3,4). Experimental data from Kellogg and others (2003) showed that *Leersia* will germinate over a wide-range of hydrologic conditions and organic soil content, but that greater biomass production occurs in soils with moderate to high organic matter (25-50%). They also reported that *Leersia* was often an opportunistic germinator with rapid seedling growth after disturbances occurred. The soil carbon content at our survey site was more than adequate for *Leersia*. Its dominance in transect C and other lower nutrient sites may be due to its ability to germinate opportunistically and take advantage of structural spaces that occur between individual stands of *Typha*. This intermix of *Leersia* and *Typha* was common throughout our sampling area with the exception of plots B20 and B40. Kellogg and others (2003) also found *Leersia oryzoides* and *Scirpus cyperinus* were abundant and characteristic of early successional wetlands. *Scirpus cyperinus* was observed occasionally to frequently throughout our study area, but did not occur in our study plots.

Of the three dominant species, *Sparganium* was the only one that was absent from more than one sample plot (Fig. 2). It is strongly correlated with standing surface water and appears to be restricted to sites of adequate depth (CCA, Figs. 3,4). Nutrient enrichment experiments by Neely and Davis (1985) indicate that *S. eurycarpum* produces greater biomass with increased interstitial nutrients. Water levels appear to favor *Sparganium* at plot C10, however the lower nutrient concentrations at this site may give a competitive advantage to *Leersia*. Further chemical data would be needed to determine whether these conditions persist throughout the year.

Phragmites australis (common reed grass) was observed at a few places within the study area near transect A and plot C10. Control of this species is imperative due to its known noxious weed status and invasive habits. *Phragmites* can replace species with specialized habitat requirements and decrease their overall numbers (Findlay and others 2002). It produces about twice the above ground biomass as the plants it replaces and sequesters nitrogen up to 7 times greater per unit area than in *Typha* (Findlay and others 2002). These characteristics and others allow *Phragmites* to establish itself in harsh environments and facilitates its invasiveness. At present, it appears that the *Phragmites* in our site area is still at a manageable status and should be removed before it invades the entire area. One individual of *Lythrum salicaria* was found on our initial site visit and can also be controlled if immediate removal steps are taken.

CONCLUSION

Macrophyte diversity in our site was low and the FQI points to a community indicative of altered and degraded wetlands. No individuals of *Typha latifolia* were identified at the study site, however several high quality plants were present, though in low numbers. Several aggressive species were present and dominated the site (*Typha angustifolia* and *Leersia oryzoides*) and *T.* x *glauca* has been identified in the wetland, though not along our transects. The ability of invasive species to overtake an area is due in part to both plant traits and habitat modifications (Woo and Zedler 2002). Canonical correspondence analysis showed that the dominant species were correlated with nutrient and hydrologic conditions at the site. Historic and recent land-use information indicates these conditions are the result of anthropogenic modifications and impacts. At least two non-native aggressive invasive plants, *Phragmites australis* and *Lythrum salicaria* were found within the study site and appear to be controllable at this point.

The long-term history of human impact at our specific site precludes restoration of a high quality wetland vegetation community, if indeed one even existed. However, active removal of aggressive invasive species and better control of land-use impacts particularly from surrounding domestic home septic systems would improve the condition of this section of the Lake Abram wetland. Unless these stresses are controlled, attempts to introduce new, more desirable species will likely fail. Given the urban stressors on the site, any enhancement of the vegetation community needs to take into account the existing conditions. Introduction of nutrient-tolerant native species and soil transplantation from other sites with known viable seed banks are options to be considered. Recent mitigation wetlands created along Abrams Creek at the southern entrance to the wetland appear to be successful in the initial establishment of a diverse plant community. This indicates that with proper planning, rehabilitation efforts to the Lake Abram wetland can be successful.

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